

## APPENDIX D. CRUISE SHIP STATIONARY DISCHARGE MODELING

The Science Advisory Panel concluded in *The Impact of Cruise Ship Wastewater Discharge on Alaska Waters*, November 2002 report that wastewater discharges from vessels moving at a minimum of 6 knots, 1 mile from shore, met water quality standards.<sup>1</sup> The Panel also concluded that wastewater treated by an advanced treatment system and discharged from a stationary vessel, within limits specified by the federal law for continuous discharge certification, limits the impact on Alaska water. The Panel made a dilution assumption for stationary vessels using the EPA approved CORMIX model which calculates the dilution a waste water discharge can be expected to experience under certain conditions. This model showed that a discharge rate of 50 m<sup>3</sup>/hr yields a dilution factor of 36 at a distance about 4.5 m from the ship and a dilution factor of 50 at 7 m from the ship after 43 seconds.<sup>2</sup>

ADEC subsequently modeled the dilution of wastewater that is discharged from stationary cruise ships using the EPA approved Visual Plumes model and vessel specific information in order to verify the assumptions made by the Panel in the November 2002 report.<sup>3</sup> The ADEC routinely uses Visual Plumes instead of CORMIX to model discharges into the marine environment. The resulting dilution factor was used to determine whether a pollutant's effluent concentration would meet Alaska water quality standards.

Neither the Visual Plumes nor CORMIX model is designed for cruise ships. A boundary layer is formed by the hull of a ship. Neither model takes into account the momentum needed to break through this boundary layer. Some of the pump pressure, producing jet like propulsion, is needed to break through this boundary layer. Ports and harbors have minimum wave action by design, which reduces far field dilution effects. Docks can also trap wastewater effluent and prevent it from mixing with ambient sea water. The effluent's temperature and salinity affects its density, which in turn affects the water's ability to disperse.

ADEC used information provided by the cruise ship companies in their Vessel Specific Sampling Plans (VSSP) to input into the Visual Plumes model. This information is found in Table 1 and Table 2. The Visual Plumes model calculates a dilution factor of 1 for above the water line discharges even in areas of large currents even though some dilution must exist because of the currents. This is because the model uses the elevation above the sea floor in its calculations. In cases where discharges occur above the water, the elevation exceeds the maximum. The ADEC consulted with a physical oceanographer on the Science Panel who suggested assuming the discharge occurred just under the waterline. In order to use the Visual Plumes model which is designed for discharges below the water surface, ADEC treated ships that discharge above the waterline as if they were discharging 5 centimeters below the waterline.

ADEC modeled stationary discharges from large ships that visit Juneau, Ketchikan, and Skagway during a neap tide.<sup>4</sup> These towns are located in Southeast Alaska's Inside Passage and were chosen based upon the high number of vessel visits per year. The lowest dilution factor generally occurred

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<sup>1</sup> Science Advisory Panel "The Impact of Cruise Ship Wastewater Discharge on Alaska Waters", November 2002 located at <http://www.state.ak.us/dec/press/cruise/documents/impact/executivesummary.htm> Section I.

<sup>2</sup> Science Advisory Panel "The Impact of Cruise Ship Wastewater Discharge on Alaska Waters," November 2002, Appendix 8 located at <http://www.state.ak.us/dec/press/cruise/documents/impact/appendix8.htm> footnote 1.

<sup>3</sup> ADEC used the PLUMES mode UM3 with the Brooks far field solution. For more information on this model go to <http://www.epa.gov/ceampubl/swater/vplume/>

<sup>4</sup> A tide of minimum range occurring at the first and the third quarters of the moon.

in Skagway whereas Juneau and Ketchikan have higher ambient currents even during NEAP tide. Juneau harbor experiences a large eddy in their harbor, created by currents in Gastineau channel.

Skagway is located at the end of Lynn Canal and is not affected by open ocean effects. Large storms in the winter cause upper Lynn Canal to mix.<sup>5</sup> Skagway sits on the Taiya Inlet at the outfall of the Skagway River. During the neap tides of July 2003, the overall current was small and direction variable. There was slight ebb flow moving water away from Skagway that was inputted as far field dilution. The data on the salinity and water temperature stations was taken from the town's ambient monitoring stations submitted in their Federal National Pollution Discharge Elimination System (NPDES) permit application. The data shows the water in the central dock area is brackish with low salinity. The town has docking space for four large cruise ships, the AMHS ferry, and a small cruise ship.<sup>6</sup> A fifth large ship could dock at the ferry dock, if needed. The water at the western most cruise ship dock has higher salinity and temperatures than at the ferry/cruise ship dock in the center.

Ambient data was also inputted into the model. This information came from various sources including software program *Chart Navigator* and ambient data used on other ADEC water modeling projects. ADEC modeled the wastewater discharged under worst case scenario, during the neap tides that occurred on July 7 and July 21, 2003. The flow was the same on both days. The ambient data used for the model is included in Table 3.

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<sup>5</sup> Douglas, Robert McLain. Heat and Water Balance of Lynn Canal. Historical section State Library, 1969.

<sup>6</sup> Town of Skagway at [http://www.romancingalaska.com/southeast/SE\\_skagway\\_map.htm](http://www.romancingalaska.com/southeast/SE_skagway_map.htm)

**Table 1. Large Ship Information used in Visual Plumes Model**

Ship Name	Port diameter (cm)	Port depth from Water line <sup>7</sup> (meters)	Effluent Flow		
			Flow Rate gal/min (MGD)	Temperature C	Salinity Psu
Coral Princess	60.0	-2.5	133 (0.191)	32.4	0
Dawn Princess	8.0	-2.8	133 (0.191)	31	0
Island Princess	60.0	-2.5	133 (0.191)	35.45	0
Pacific Princess	16.0	-3.6	133 (0.191)	30.35	0
Star Princess	10.0	-2.5	133 (0.191)	34	0
Sun Princess	10.0	-1.3	133 (0.191)	31.9	0
Carnival Spirit	10.0	+0.5	220 (0.317)	25.35	0
Mercury	10.0	-1.0	613 (0.883)	19.8	0
Norwegian Sky	10.0	-5.0	154 (0.222)	28.5	0
Norwegian Sun	10.0	-2.0	660 (0.950)	27	0
Norwegian Wind	10.0	-3.0	265 (0.382)	32.8	0
Seven Seas Mariner	5.0	-4.0	33 (0.0475)	79.34	0
Maasdam	7.6	-2.0	618 (0.1728)	25.9	0
Ryndam	7.6	-2.0	618 (0.1728)	26.35	0
Statendam	10.0	-2.0	618 (0.1728)	23.1	
Veendam	7.6	-2.0	618 (0.1728)	28.85	0
Volendam	7.6	-2.0	618 (0.1728)	28.15	0
Zaandam	7.6	-2.0	618 (0.1728)	27.25	0

**Table 2. Small Ship Information used in Visual Plumes Model**

Ship Name	Port Diameter (cm)	Port Depth from Water line <sup>8</sup> (meters)	Effluent Flow		
			Flow Rate Gal/min (MGD)	Temperature C	Salinity Psu
Clipper Odyssey BW	6.50	-1.200	150.0 (0.2160)	15.8	14
Clipper Odyssey GW	6.50	-1.000	150.0 (0.2160)	20.7	0
Columbia BW&GW	Unknown	Unknown	10.0 (0.0140)	16.7	10
Empress of the North BW&GW	1.27	0.000	15.0 (0.0210)	17.7	5
Kennicott BW&GW	10.16	0.152	10.0 (0.0140)	17.3	10
Malaspina BW&GW	Unknown	Unknown	10.0 (0.0140)	16.7	10
Matanuska BW&GW	10.02	-0.610	10.0 (0.0140)	21.7	10
Sea Bird GW	5.10	0.152	45.0 (0.0650)	19.6	0
Sea Bird BW	7.60	0.152	2.5 (0.0040)	14.9	14
Sea Lion GW	5.10	0.152	45.0 (0.0650)	19.6	0
Sea Lion BW	7.60	0.152	2.5 (0.0040)	14.9	14
Spirit of 98 BW	5.10	-0.305	3.0 (0.0040)	19.6	
Spirit of 98 GW	10.20	-0.152	5.0 (0.0070)	29.9	0
Spirit of Alaska BW	5.10	0.152	0.2 (0.0003)	35.5	14

<sup>7</sup> The negative numbers are inputted as positives in the model.

<sup>8</sup> The negative numbers are inputted as positives in the model.

Ship Name	Port Diameter (cm)	Port Depth from Water line <sup>8</sup> (meters)	Effluent Flow		
			Flow Rate Gal/min (MGD)	Temperature C	Salinity Psu
Spirit of Alaska GW	5.10	0.152	0.2 (0.0003)	30.4	0
Spirit of Columbia BW	3.80	0.152	5.0 (0.0070)	14.6	14
Spirit of Columbia GW	5.10	0.152	10.0 (0.0140)	17.3	0
Spirit of Discovery BW	6.40	0.152	5.0 (0.0070)	19.4	14
Spirit of Discovery GW	7.60	0.152	5.0 (0.0070)	38.0	0
Spirit of Endeavour BW	7.60	0.152	5.2 (0.0080)	19.7	14
Spirit of Endeavour GW	7.60	0.152	16.0 (0.0230)	20.3	0
Spirit of Oceanus BW&GW	12.70	-1.00	90.0 (0.1300)	24.6	2
Taku BW&GW	15.20	0.610	75.0 (0.1080)	16.7	10
Wilderness Adventurer BW&GW	5.10	-0.051	2.60 (0.0040)	18.0	0
Wilderness Discoverer BW&GW	5.10	-0.051	2.60 (0.0040)	18.5	0
Yorktown Clipper BW	10.20	0.000	5.2 (0.0080)	17.0	14
Yorktown Clipper GW	7.60	0.000	25.0 (0.0360)	23.5	0

**Table 3. Ambient Water Assumptions in Skagway during NEAP tide July 7, 2003 and July 21, 2003**

Depth (feet)	Near Field		Ambient <sup>9</sup>		Far Field	
	Speed (knots)	Direction (degrees)	Salinity (psu)	Temp (C)	Speed (knots)	Direction (degrees)
0	0	90	5	12	.45	90
5	0	90	5	12	.45	90
10	0	90	7	12	.45	90
15	0	90	14	9	.45	90
20	0	90	19	7	.45	90
25	0	90	19	7	.45	90
30	0	90	19	7	.45	90
35	0	90	19.5	7	.45	90
40	0	90	20	6.5	.45	90
45	0	90	20	6	.45	90
50 (floor)	0	90	20	6	.45	90

## MODELING RESULTS

The dilution factor for stationary large ships in Skagway during a neap tide ranged from 5 – 60. The dilution factor for small ships ranged from 1 – 60. These Skagway dilution factors are used throughout the report.

<sup>9</sup> ADEC George, Kenwyn. Skagway ENSR Modeling 7/30/03 WQ Station1 located at the Cruise Ship/Ferry Dock  
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**Table 4. Dilution of Stationary Discharge from Large Ships during Neap Tides**

Ship Name	Skagway	
	Max Dilution Factor	Reached @
Coral Princess	10	1.0 m
Dawn Princess	24	4.0 m
Island Princess	8	<1.0 m
Pacific Princess	10	1.5 m
Star Princess	20	4.0 m
Sun Princess	15	2.5 m
Carnival Spirit	5	<1.0m
Mercury	18	4.0 m
Norwegian Sky	14	2.0 m
Norwegian Sun	30	7.0 m
Norwegian Wind	24	5.0 m
Seven Seas Mariner	18	2.0 m
Maasdam	60	5.0 m
Ryndam	60	5.0 m
Statendam	45	4.0 m
Veendam	60	5.0 m
Volendam	60	5.0 m
Zaandam	60	5.0 m

**Table 5: Dilution of Stationary Discharge from Small Ships during Neap Tides**

Ship Name	Skagway	
	Max Dilution Factor	Reached @
Clipper Odyssey BW	38	5.8 m
Clipper Odyssey GW	30	4.5 m
Columbia BW&GW mixed	Unable to Model	Unable to Model
Empress of the North BW&GW mixed	30	1 m
Kennecott BW&GW mixed	23	< 1 m
Malaspina	Unable to Model	Unable to Model
Matanuska BW&GW mixed	1.5	2 m
Sea Bird GW	2.5	20 m
Sea Bird BW	60	20 m
Sea Lion GW	2.5	20 m
Sea Lion BW	60	20 m
Spirit of 98 BW	44	1 m
Spirit of 98 GW	2.5	1 m
Spirit of AK-BW	60	< 1m
Spirit of AK - GW	60	< 1m
Spirit of Columbia BW	50	< 1m
Spirit of Columbia GW	2.5	< 1 m
Spirit of Discovery GW	5	< 1 m
Spirit of Discovery BW	40	< 1 m
Spirit of Oceanus BW&GW mixed	8	1.5 m

Ship Name	Skagway	
	Max Dilution Factor	Reached @
Taku BW&GW mixed	1	< 1 m
Wilderness Adventurer BW&GW mixed	20	< 1m
Wilderness Discoverer BW&GW mixed	20	< 1m
Yorktown Clipper BW	40	< 1 m
Yorktown Clipper GW	1.5	< 1 m